ANNUAL REPORT ON RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS

FY 1980

HUGH L. DRYDEN
FLIGHT RESEARCH CENTER

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DRYDEN FLIGHT RESEARCH CENTER ANNUAL REPORT

ON RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS

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INTRODUCTION

This report highlights the research and technology (R & T) accomplishments of the Dryden Flight Research Center in FY 1980. Individual items in this report are arranged under the five NASA Program Offices that sponsor the R & T activities, and items within each Program Office are arranged according to the agencywide Research and Technology Objectives and Plans (RTOP) work breakdown structure. Accomplishments in specific areas can be identified through use of the Table of Contents, which lists major program and subprogram titles, as well as individual items. Additional information may be obtained by contacting the individuals named at the end of each item.

The Dryden Flight Research Center is primarily engaged in conducting flight research into vehicle, systems, piloting, and operational problems. Dryden develops or modifies both piloted and remotely piloted aircraft where necessary for performing flight research. Many Dryden programs are conducted jointly with other NASA installations or government agencies. Dryden also performs or sponsors advanced planning and studies of potential flight research programs to address technology areas of interest. In addition, Dryden conducts or sponsors supporting research in instrumentation, flight test techniques, piloting, flight systems, guidance, communications, crew functions, and air vehicles.

FY 1980 has been an active and productive year at Dryden, with activities ranging from shuttle tile tests to support the space shuttle program to conducting a wide variety of aeronautics programs. First flights were made on the AD-1, DAST I, F-14 (ARI), and F-111 aircraft with natural laminar flow (NLF) modifications. Dryden has acquired a new VTOL test facility from the Air Force Flight Test Center to support VTOL flight research, and the tilt rotor research aircraft arrived at the Center for flight tests in FY 1981. One of the two control rooms for the new mission control center attained operational status during FY 1980, and the second will be operational by the end of CY 1980 to support shuttle missions. The results of R & T work have been or soon will be presented in technical papers or reports. The technical reports, papers, and articles published in FY 1980 are listed at the end of this volume, as is a summary of the R & T flight activities.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

AERONAUTICS RESEARCH AND TECHNOLOGY BASE

Fluid Physics Research and Technology

Three-Dimensional Flow Separation About a Slender Cone at High Angles of Attack. - The prediction and control of flow separation and the paths of the ensuing vortices about the leeward of forebodies is important for vehicles that must fly at extreme attitudes. For a fighter aircraft or missile to be successful throughout a wide range of flight conditions, the aerodynamic design must ensure that there is adequate control with no adverse changes in force and moment characteristics. At high angles of attack, the three-dimensional flow separations and vortices may become asymmetric with respect to the pitch plane of the vehicle. In passing downstream, the asymmetric vortices may interfere with control surfaces and provide nonlinearities and side forces that are not readily predictable.

The slender cone is the simplest shape of forebody that one may envisage. It provides a convenient model configuration to investigate forebody turbulent flows with symmetric and asymmetric separation since the circumferential pressure gradients completely dominate the development of the three-dimensional flow. Hence, there is no strong dependence of the flow structure on axial position along the body. Wind-tunnel measurements with a 10° cone have documented the development of the leeward separated flow, but background noise and tunnel freestream fluctuation levels may have contaminated the fluctuating pressure signature at the model surface to increase the amplitude. In addition, the variation in amplitude of the wind-tunnel fluctuating pressure measurements appeared opposite to results obtained in regions of two-dimensional separation. As a consequence, static and fluctuation pressure data have been obtained in flight with a 10° cone mated to an F-15 airplane at subsonic and supersonic Mach numbers. Sample results at M = 1.5 and at a length Reynolds number of 11.5×10^6 are illustrated in the accompanying figure. The

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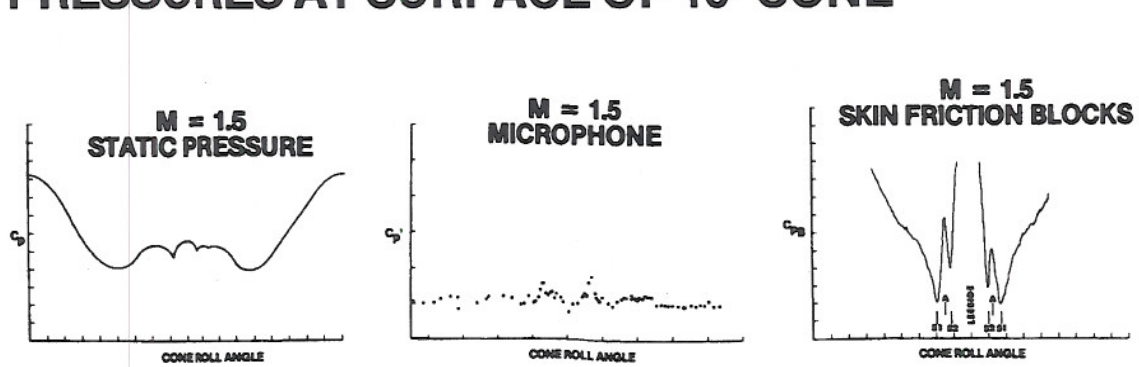
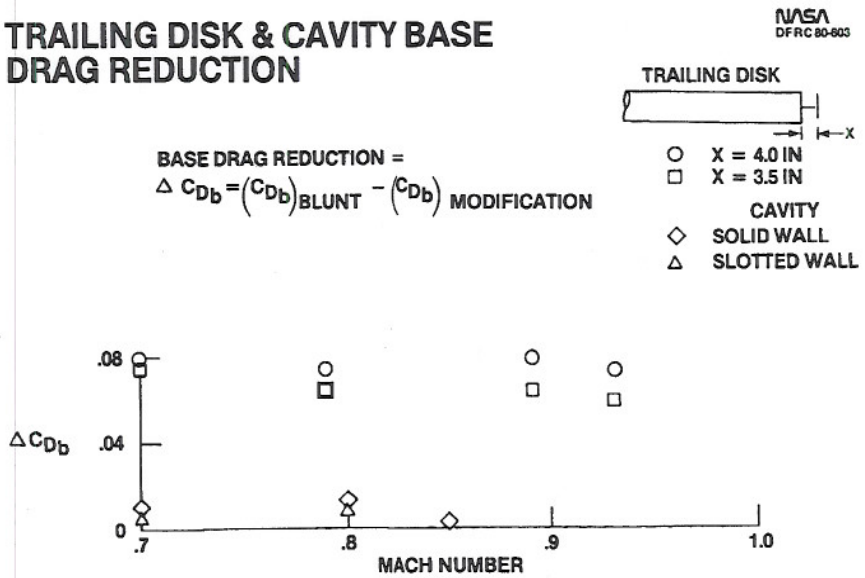


mean pressures and separation line positions (obtained with skin friction "obstacle blocks") compare closely with corresponding wind-tunnel Navier-Stokes calculations. The root-mean-square amplitudes of the flight fluctuating pressure data show typically the same trends as the wind-tunnel information but are about one order less in magnitude. Such a result is clearly important when extrapolating wind-tunnel fluctuating pressure amplitudes beneath leeside separated flows to full scale on a general configuration.

Initial results have been reported in AIAA Paper No. 80-1422, and detailed analysis is to be presented at the AIAA 19th Aerospace Sciences meeting, January 1981. (David Fisher, ext. 379)

3-D Base Drag Reduction Study. - Low speed, low Reynolds number, turbulent flow wind-tunnel experiments conducted during the mid-1960's on a body of revolution with a blunt base showed that the base drag could be substantially reduced by mounting a disk behind the body. This disk, which had a diameter smaller than that of the body, provided the basis for an aerodynamic boattail by generating a "trapped vortex". The drag reduction resulting from the presence of the trailing disk was dependent on the separation distance between the base of the body of revolution and the trailing disk and on the diameter of the disk relative to the diameter of the body.

A flight investigation of the trailing disk concept was conducted at Dryden on a body-of-revolution shape at the top of the F-111 TACT airplane vertical fin. The flight results showed that the trailing disk reduced the blunt base axisymmetric drag by approximately 1/3 over the Mach range from 0.7 to 0.95. Subsequent tests in the Langley High-Speed 7- by 10-Foot Tunnel for a full-scale model correlated well with these results.



Recent low speed, low Reynolds number, turbulent flow wind-tunnel studies showed that blunt body base drag could also be reduced by the installation of a cavity at the

base. The drag reduction was determined to be dependent on the cavity depth relative to the base diameter and on whether the cavity wall was solid or ventilated. Two of the most effective of these cavity configurations were tested in flight on the F-111 TACT vertical fin body-of-revolution. Although the cavity shapes are easier to fabricate and install, the results obtained showed only slight reductions in the base drag. It is considered that the trailing disk configuration is substantially more effective in reducing the base drag. (Sheryll Powers, ext. 378)

Materials and Structures Research and Technology

B-1 Loads Research. - Structural, wind-tunnel, and flight data from the B-1 Air Force development program are being obtained under contract to the manufacturer as part of an overall investigation of airload measurement techniques and aeroelastic load prediction methods.

Wind-tunnel and flight data for transonic Mach numbers, and the final substructure of a NASTRAN structural model of the B-1 were delivered to Dryden in FY 1980. The FLEXSTAB/NASTRAN system was operationally checked out on the Dryden computer. In-house aeroelastic airload predictions from these models are being compared with wind tunnel and flight results. (Alan Carter, ext. 453)

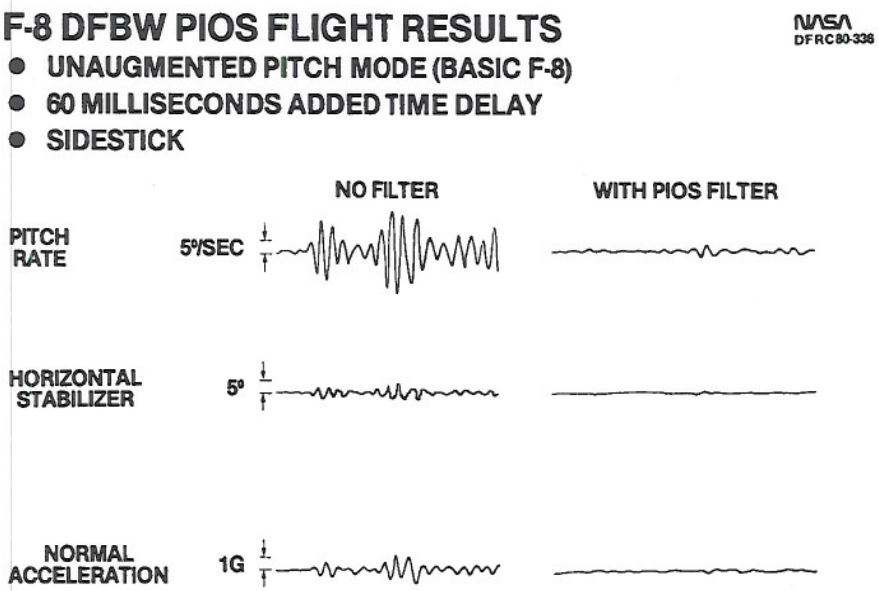
DAST I. - Three flights have been performed on the modified Firebee II (BMQ-34 E/F supersonic target drone) used in the drones for aerodynamics and structural test (DAST) program. The second flight, flown in April 1980, established the open-loop flutter boundary for the ARW-1 wing and exercised the flutter suppression system at speeds below the flutter speed. High quality test data was obtained. The signal-to-noise ratio of the structural responses to given input excitation was considerably improved over that normally obtained in transonic wind tunnel testing.

In June 1980, the third flight with the ARW-1 was performed. Testing was conducted between 0.675 and 0.825 Mach number. At 0.825 Mach number explosive flutter was encountered with the flutter suppression system on and the right-hand wing failed. A post-flight analysis revealed an error in the flutter suppression system gain settings which made the vehicle vulnerable to the flutter encountered. The test vehicle is to be rebuilt, and testing will resume in approximately 1 year. (William Andrews, ext. 613)

Aeroelastic Tailoring. - The HiMAT wing and canard were fabricated from boron epoxy composites, using nonsymmetric lay-ups. Deflections measured during proof tests of the vehicle indicated significantly greater torsional stiffness than predicted from a detailed NASTRAN structural analysis employing anisotropic elements. Correlation of predicted and measured stresses was considered unsatisfactory, as well.

To investigate these discrepancies, coupons of the wing material were tested to better characterize the material and an ultimate load test of a wing will be conducted. Analyses will be performed using state of the art computer programs which consider nonlinearity and hysteresis in the composite material properties. Resolution of these questions is essential to establish confidence in aeroelastic tailoring technology. (Richard Monaghan, ext. 640)

Nonlinear Pilot Prefilters. - As an extension of the work performed to develop a nonlinear filter to suppress pilot-induced oscillations (PIO), flight research is being conducted to explore general applications of this technology. Pilot-induced oscillation suppression filters have been evaluated in flight using the Dryden F-8 digital fly-by-wire research aircraft. Artificial time delays were inserted in the pilot command path to induce pilot-induced oscillations. The effectiveness of the suppression filters was then evaluated. The figure shows an example of the flight test results. A PIO occurring during simulated refueling is suppressed using the nonlinear filter. (James Stewart, ext. 331)



Resident Backup Software. - A hybrid hardware/software method has been developed to provide a significant degree of protection from common-mode software faults in redundant digital flight control systems. The method utilizes a detection scheme based on the recognition of a software self-test alarm which occurs near simultaneously in all redundant channels. The detection hardware triggers an interrupt in each computer, forcing them to begin execution of alternate software. The system has been evaluated on the Dryden F-8 digital fly-by-wire iron bird facility. This approach offers the potential of providing an alternative approach to independent backup hardware for digital fly-by-wire control systems. (Wilton Lock, ext. 494)

Multidisciplinary Research

Low Cost Parameter Identification. - A self-contained instrumentation system, suitable for use aboard light aircraft, along with desk-computer software has been developed to permit low cost parameter estimation for the extraction of aerodynamic coefficients. The method and hardware have been validated during tests using light aircraft at the University of Kansas. The approach taken was designed to minimize aircraft modifications and utilize hardware which is inexpensive to purchase and integrate. The

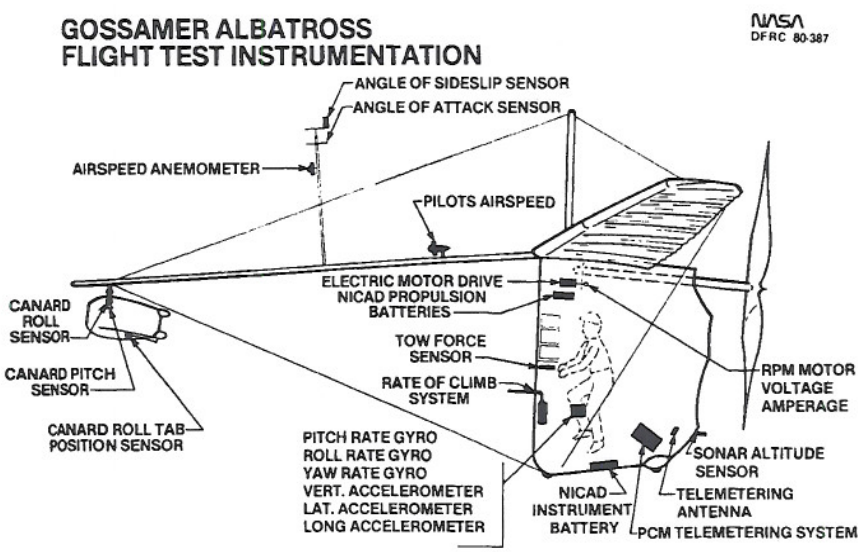
software package is based on the maximum likelihood estimation scheme developed at Dryden, and is designed to be run on available desk top computer systems, using a cassette data tape generated during flight. (Kenneth Szalai, ext. 517)

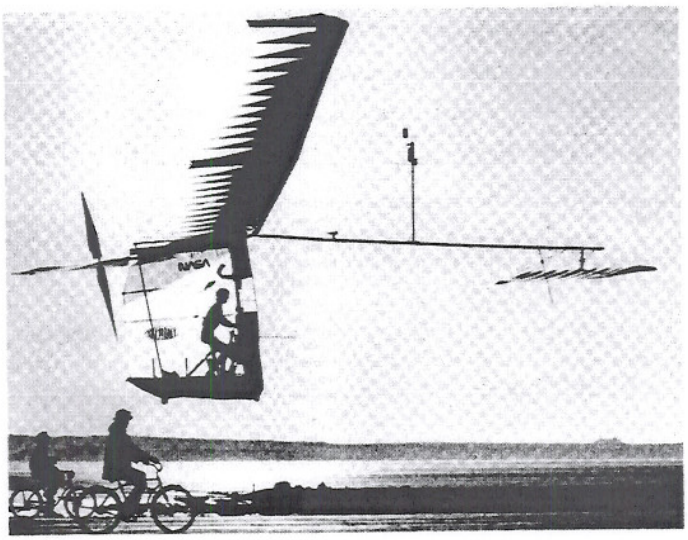
General Aviation Research and Technology

Gossamer Albatross Flight Test Program. - A small flight investigation of the MacCready Gossamer Albatross Number 2 (a backup aircraft identical to the English Channel Aircraft Number 1) was jointly sponsored by NASA Langley and NASA Dryden and conducted at NASA Dryden, to determine stability, control, and performance characteristics of an ultra-low-wing-loading aircraft. Seventeen flights were flown on the aircraft powered by an electric (battery) propulsion system giving a 15-minute flight duration on a 6-pound Ni-Cad battery pack. The flight data (19 channels of data transmitted to a ground receiving station) from the aircraft was recorded while Bryan Allen maneuvered the craft through planned research maneuvers to extract stability, control and performance data.

The craft was also flown in propeller-off towed flight in order to extract propeller effects on flight characteristics. Also, special tests involving the jettisoning of weights in flight from the aircraft centerline and wingtips were devised to determine the "apparent mass" effects of this type of aircraft. The "apparent mass", or translated air mass, which is usually insignificant in heavier aircraft, was found to affect the flying characteristics significantly by making the aircraft appear to have three times its normal mass in vertical translations and five times its roll inertia in roll motions.

The flight data is being analyzed to determine if some of the radical structural and aerodynamic ideas may be useful in designing a microwave or solar powered "flying platform" to be stationed at an extremely high altitude to serve as a communications link, pollution monitor, and observer of surface resources. The results of these flight tests will be presented in a report. (R. Dale Reed, ext. 402)





Flight Evaluation of a General Aviation Terminal Guidance System. - A flight test program to evaluate a system capable of providing guidance along a curved descending flight path to landing was completed. This program was performed by California Polytechnic University under a grant from the NASA Dryden Flight Research Center. A Cessna 182 was used as the test aircraft, and the system utilized the aircraft altimeter, DME, RMI, and gyro compass. A total of 230 approaches were flown, utilizing three pilots. Results indicate that the terminal guidance system will provide accurate guidance for curved descending approaches which can be followed by pilots with reasonably low instrument time. As illustrated in the figure, the curved

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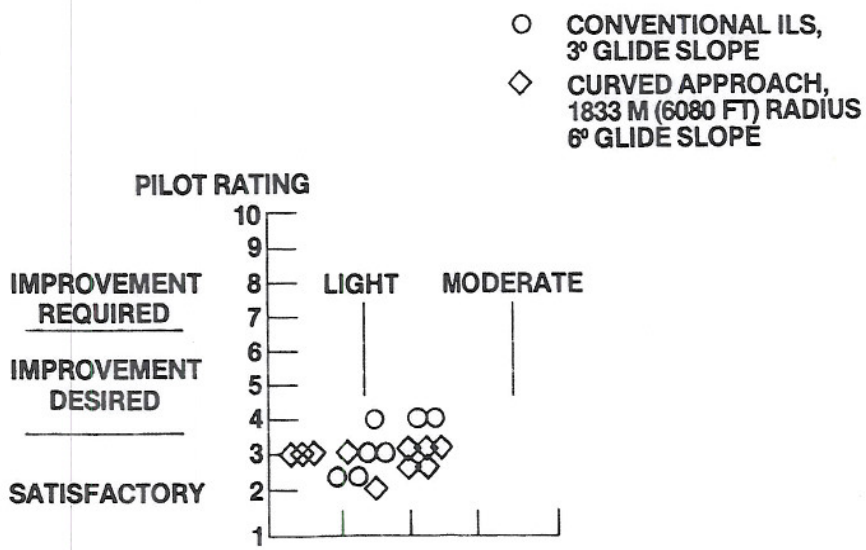
PILOT RATINGS FOR CONVENTIONAL ILS AND CURVED APPROACH TASKS



approaches are similar in difficulty to conventional 3° approaches. Although the system does precisely align the aircraft with the runway for landing, the system is not designed to correct to a given flight path over the ground to compensate for wind drift. Consequently, its usefulness is limited to airspace where deviation from a given flight path is not critical. (Donald Berry, ext. 793)

High-Speed Aircraft Research and Technology

Flight Dynamics and Handling Qualities. - In recent years, overcontrol and pilot-induced oscillation tendencies have been experienced by several advanced aircraft, and control system time delays have been identified as contributing factors. Because of the sampling and computational delays of digital computers, digital flight control systems can exhibit a pure time delay that is significantly different from that experienced by previous generations of aircraft. Analyses of data from the F-8 DFBW airplane were recently completed that provided designers valuable information on the effects of pure time delays on aircraft handling qualities. Handling qualities relate to the ease and precision with which a pilot can accomplish a given task. An overall figure of merit is the pilot rating, where the higher the pilot rating number, the worse the rating. Results from the F-8 DFBW airplane indicate that the effect of pure time delays on pilot rating is strongly influenced by task, as illustrated in the accompanying figure.

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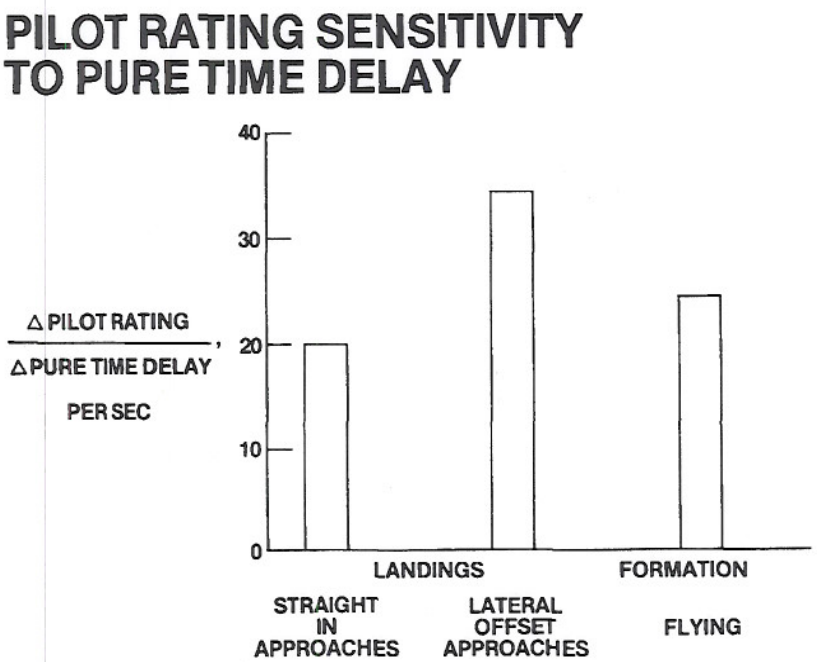

It can be seen that landings with a lateral offset were twice as sensitive to pure time delay as straight-in landings, and even more sensitive than formation flying. These data will assist designers in determining how much pure time delay can be tolerated in aircraft flight control systems. (Donald Berry, ext. 793)

Parameter Estimation and High-Angle-of-Attack Research. - A new formulation of the parameter estimation problem in the presence of process noise and measurement noise has been published and implemented in the MMLE-3 program. The MMLE-3 program has been disseminated to numerous government and contractor organizations.

Results from the spin research vehicle (SRV) program have been published. These data show the repeatability of the spin modes and, at the same time, the sensitivity of the spin modes to small configuration changes. For example, slight discrepancies in vehicle alignment, or the presence of a nose boom, made significant differences in spin behavior. (Kenneth Iliff, ext. 724)

High Speed Inlet Noise Suppression. - The mixed compression inlet of the YF-12 aircraft has been found to be effective in attenuating engine compressor noise, both statically and in flight. Static tests have been conducted with the J58 engine in a ground test stand, and also installed in the YF-12. Instrumentation consisted of steady state total and static pressures and dynamic transducers in the inlet and an array of far-field microphones. Engine rpm, inlet spike position, bypass position, and bleed position were varied.

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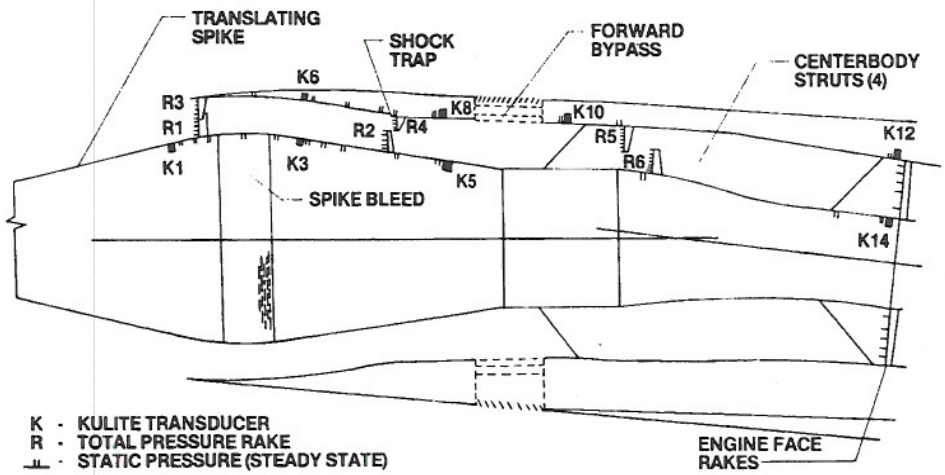
YF-12 INLET INSTRUMENTATION FOR INLET NOISE INVESTIGATION



In the figure below, the installed engine narrow band spectrum is compared to that produced by the engine on a test stand at an angle of 40°. The presence of the inlet eliminates the multiple pure tones. The blade passing frequency is reduced by 20 db and spread so that no distinct tone is even present. The perceived noise level is reduced by 11 db. This noise reduction occurs with a maximum Mach number in the inlet of less than 0.6. Short inlets normally produce almost no noise reduction at such low Mach numbers.

Based on these results, it is clear that some other mechanisms must be important for noise suppression in the YF-12 inlet. It is believed that the presence of the struts is important in eliminating the multiple pure tones. It is also believed that high levels of local incoherent turbulence in the inlet, caused by bleed inflow, bypass inflow, and cowl lip separation, cause extensive frequency spreading and additional absorption. These results may mean that future supersonic transports may not need as much inlet noise suppression as previously believed. However, further study of the YF-12 inlet results and of similar inlet designs is required. (Frank W. Burcham, Jr., ext. 484)

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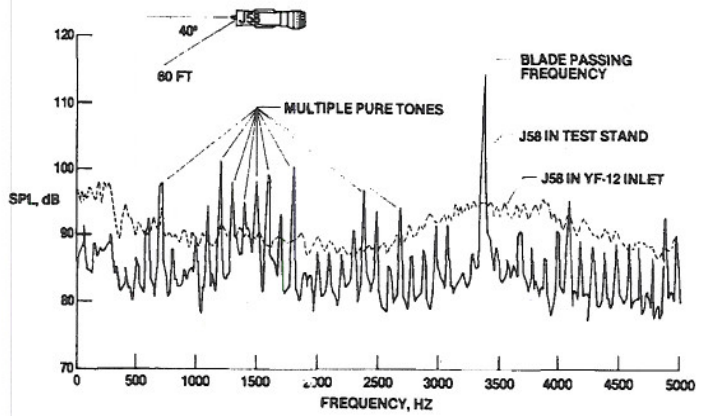
NARROWBAND SPECTRA FOR J58 ENGINE IN TEST STAND AND IN YF-12 INLET

60 FT RADIUS, 40° FROM INLET CENTERLINE, 6000 RPM



AD-1 Oblique Wing Program. - Nineteen flights have been flown, during which the principal test objective has been to establish a flutter-free flight boundary over the wing sweep angle range of 0° to 47°. An undesired low damped wing response of approximately 15 Hz has been experienced on the left hand wing in the sweep angle region of 15° to 25°. The airplane is currently grounded until a better understanding of the low damped response source can be established. Ground vibration testing and analysis of previously obtained data are being performed.

Within the flight envelopes flown to date (wing sweep up to 47°), the flying qualities are rated satisfactory. (William Andrews, ext. 613)

Transport Aircraft Research and Technology

Knowledge of High Altitude Atmospheric Processes. - The purpose of this work is to define the characteristics of atmospheric turbulence, temperature gradients, and icing conditions and their associated meteorological features. Measurements of these phenomena are obtained with instrumented aircraft, and their atmospheric environment is described by direct analysis and by use of numerical simulation

models. The objective of this work is to improve the description of atmospheric features, which strongly influence airplane design, safety, and operational economy.

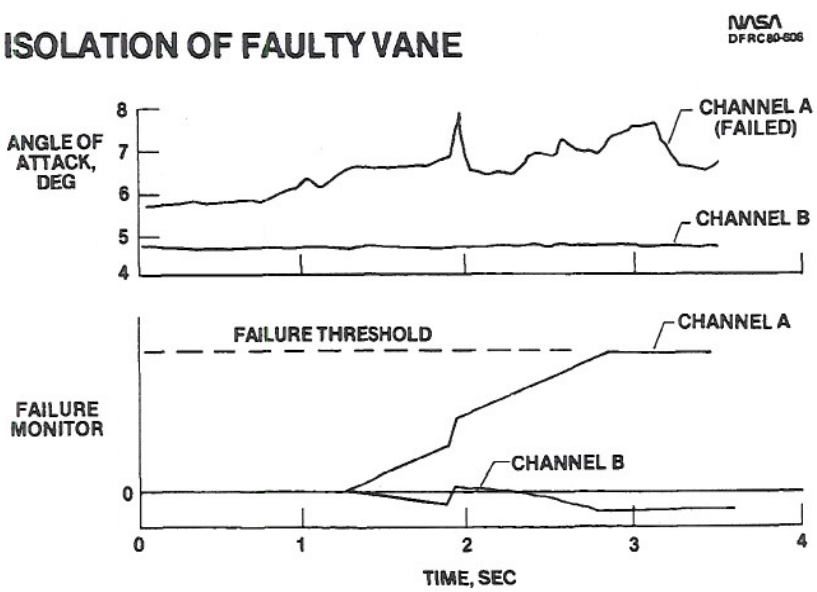
Ongoing FY 80 accomplishments include the evaluation of a mesoscale meteorological analysis computer program, to be reported in a Monthly Weather Review journal article, and a 2-D numerical simulation code of mountain wave motion to be reported in a NASA Contractor Report. The meteorological code was used to describe the atmospheric features associated with the CV-990 clear air turbulence detection flights, and the mountain wave simulation provides a useful tool to describe atmospheric conditions which induce strong turbulence. Also in preparation are a NASA Technical Memorandum on the climatology of vertical temperature gradients and wind shear layers at high altitudes, and a paper on clear air turbulence technology to be included in the Fourth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems. An ongoing study is addressed to developing a 3-D mountain wave model which will be used to examine the range of validity of the 2-D simulation.

New FY 80 endeavors include technical planning for an intercenter flight program to measure gust gradients with the B-57B airplane, and the awarding of a university grant to review cloud physics studies for results applicable to aircraft icing technology and to formulate appropriate ground and flight experiments. (Jack Ehernberger, ext. 154)

SYSTEMS TECHNOLOGY PROGRAMS

Avionics and Flight Controls Systems Technology

Analytic Redundancy Management. - Use of natural kinematic and dynamic relationships between flight control sensors permits identification of failed sensors even when only two like sensors are available. This approach, termed analytic redundancy, has the potential of substantially improving the fault tolerance of redundant flight control systems without necessitating additional sensor hardware. Flight tests of



these algorithms have been carried out using the NASA Dryden F-8 digital fly-by-wire testbed aircraft. Simulated sensor faults have been induced in cruise and maneuvering flight to validate the method. The performance of the algorithm is illustrated for an actual failure of one of two angle-of-attack vanes during one flight. The failure monitor correctly identifies the bad sensor so the remaining good sensor can be used. (Kenneth Szalai, ext. 517)

Aerodynamic Vehicle Systems Technology

Wake Vortex Studies. - NASA has been involved in a joint program with the FAA to determine the hazards associated with the wake vortices of large aircraft and to assess whether those vortices can be reduced. NASA's role in this program is to determine if aerodynamic attenuation of wake vortices is feasible and practical. Toward this end, numerous wind-tunnel and flight tests have been conducted. Deflecting the large airplane's outboard spoilers has been shown to be effective for attenuating vortices. However, the levels of attenuation achieved in this manner has not been as large as would be desired for reduced landing separation distances. Also, deflecting the spoilers has created problems of buffet and noise increases on the airplane involved.

Wind-tunnel tests to evaluate B-747 spoiler combinations (there are four outboard spoiler panels that can be deflected in various combinations) have recently been completed. The results of these tests suggested that more attenuation could be achieved using smaller deflections of different panels. To evaluate this finding, a series of tests was flown in October 1979 using a remotely controlled F-86 and a manned T-37 as probe aircraft for the wake of the B-747. This series of tests was designed to accomplish three objectives: (1) determine if a newly defined B-747 spoiler configuration yielded additional attenuation as defined by wind-tunnel tests, (2) determine if ground effects would provide additional attenuation to spoiler attenuated vortices, and (3) determine if the levels of attenuation resulting from deflected spoilers and ground effects were sufficient to allow a small airplane to land behind the B-747 at a separation distance of 3 miles.

The new spoiler configuration did result in more attenuation; however, the overall results of the tests were negative in that the remotely controlled F-86 encountered several upsets at altitudes low enough to be well within ground effect. On one occasion, the F-86 was upset to a 60° bank angle at an altitude of 60 feet. This upset occurred when the B-747 was configured with spoilers deflected for the best attenuation, and it was typical of the upsets that were encountered out of ground effect. (Marvin R. Barber, ext. 275)

Low-Speed Systems Technology

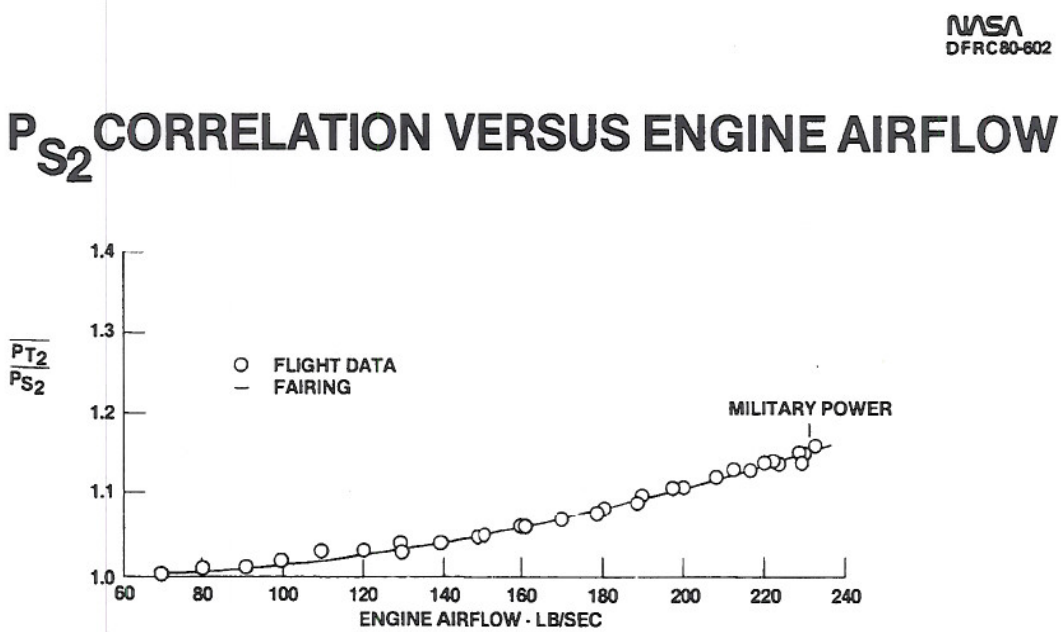
XV-15 Tilt Rotor Research Aircraft. - The Dryden Flight Research Center is working closely with the Ames Research Center to support the joint NASA/Army/Navy XV-15 tilt rotor research aircraft program. Bell Helicopter Textron has performed 76 flights on aircraft number 2 at the contractor's plant in Texas to complete the initial envelope expansion. The number 2 aircraft was delivered to Dryden on August 13, 1980, and is currently being prepared for flight status.

A VTOL test facility was acquired by Dryden from the Air Force Flight Test Center and modified to support ground tests of the XV-15 aircraft. Approximately ten government acceptance flights will be conducted in October at Dryden, followed by 70 to 100 proof-of-concept flight tests to expand the helicopter, tilt rotor, and airplane mode flight envelopes. (Weneth Painter, ext. 238)

High-Speed Systems Technology

SPF/DB Titanium Tail Structure. - Horizontal tail surfaces for a T-38 aircraft are being fabricated under contract to Rockwell International to demonstrate superplastically formed/diffusion bonded (SPF/DB) titanium structures technology. Two major advances in SPF/DB technology have been realized to date. The old two-cycle method of fabrication was reduced to a new one-cycle method, and computer-aided design was incorporated into the design, master tooling, and silk screening. The computer-aided design process has demonstrated a 50 percent reduction in design manhours when applied to a T-38 horizontal tail. The SPF/DB fabrication technique holds promise for reducing weight and manufacturing cost for future aircraft structures. (Berwin Kock, ext. 520)

A New Engine Control Parameter. - Flight tests have been conducted at Dryden on an F100 engine in an F-15 airplane which was instrumented with a single static pressure port (p_{s_2}) on a nose boom in front of the compressor face and 34 total pressure probes (p_{t_2}) at the compressor face. The purpose of the tests was to determine the potential for a new engine control parameter which uses the single static pressure measurement. The results shown in the figure below indicate that



p_{s_2} provides a predictable measure of p_{t_2} as a function of engine airflow. This measurement, along with a turbine discharge total pressure measurement, produces the engine control parameter, engine pressure ratio (EPR). If the ratio of total and static pressure is plotted against distortion, and power setting is constant, distortion tends to increase with pressure ratio, although the data show considerable scatter.

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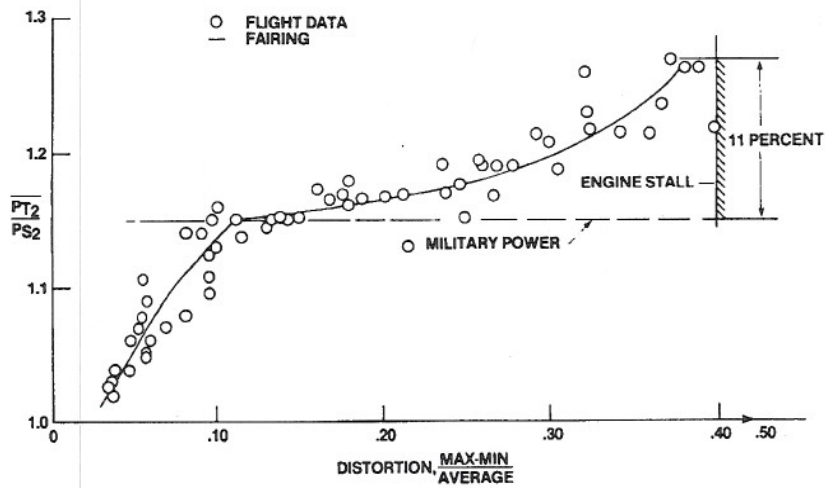
PRESSURE RATIO VERSUS DISTORTION



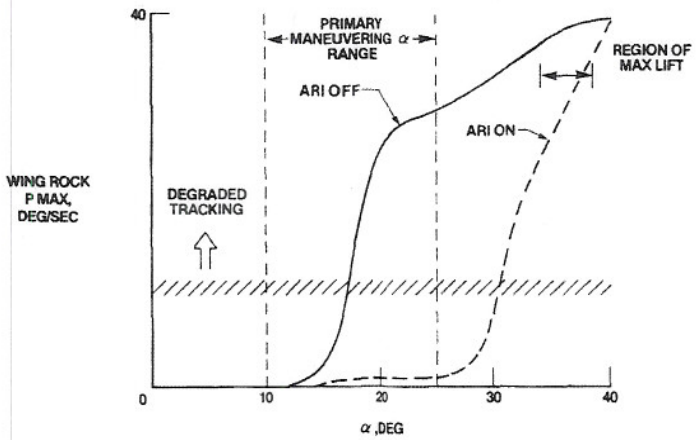
Further analysis is needed to establish a more precise correlation with other distortion indicators, such as radial and circumferential. However, these results indicate the potential for automatically downtrimming the engine with increasing inlet distortion while maintaining high engine performance with low distorted inlet flow. (Larry Myers, ext. 501)

High-Angle-of-Attack Flying Qualities. - Flight tests are being conducted at the Dryden Flight Research Center on a Navy F-14 to develop a control system modification which was designed by Langley to improve the airplane's high-angle-of-attack flying qualities and enhance its departure/spin resistance. A highly effective system which incorporates an aileron-to-rudder interconnect (ARI) has been developed for the F-14 in the clean configuration. The airplane has been demonstrated to be highly departure resistant, and roll performance is significantly improved. In addition, an undesirable wing rock phenomenon which seriously degrades tracking has been essentially eliminated in the critical angle-of-attack range for tracking. The higher-risk portion of the flight test program makes critical use of a piloted, fixed-base simulator in terms of safety and flight planning. The NASA-conceived flight control system is currently being evaluated for the F-14 equipped with external stores. (Harriet Smith, ext. 279)

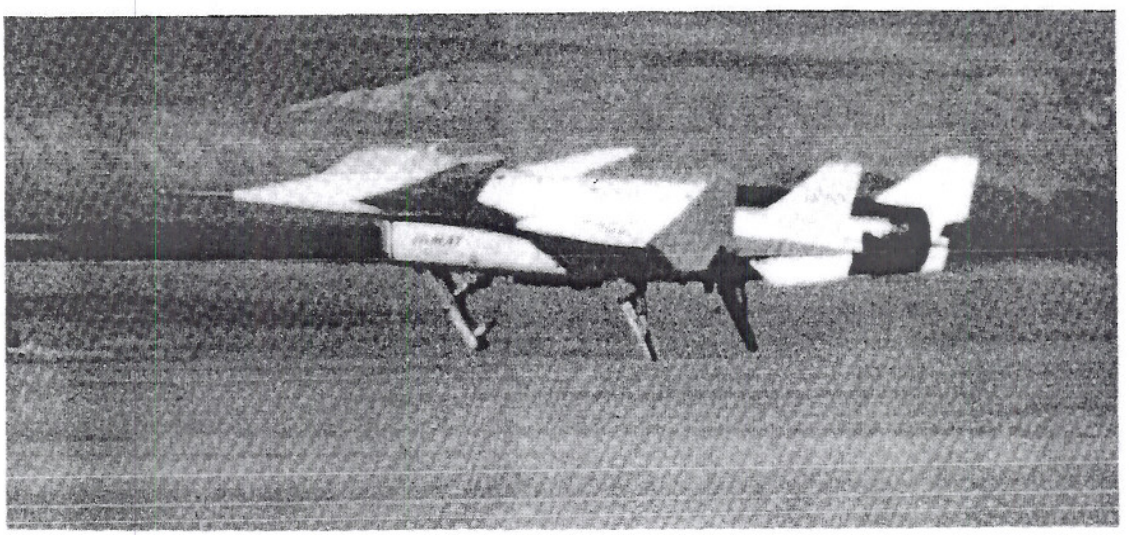
NASA
DFRC 80-224

WING ROCK SUPPRESSION PROVIDED BY THE ARI

- ARI SYSTEM USES HIGH-GAIN ROLL DAMPER AND ROLL RATE TO RUDDER FEEDBACK TO SUPPRESS WING ROCK
- ROLL DAMPER RESTRICTED TO PREVENT CROSS CONTROL COMMANDS



Highly Maneuverable Aircraft Technology (HiMAT). - Flight test of the highly maneuverable aircraft technology (HiMAT) remotely piloted research vehicle (RPRV) is underway at the NASA Dryden Flight Research Center. The initial flight phase is

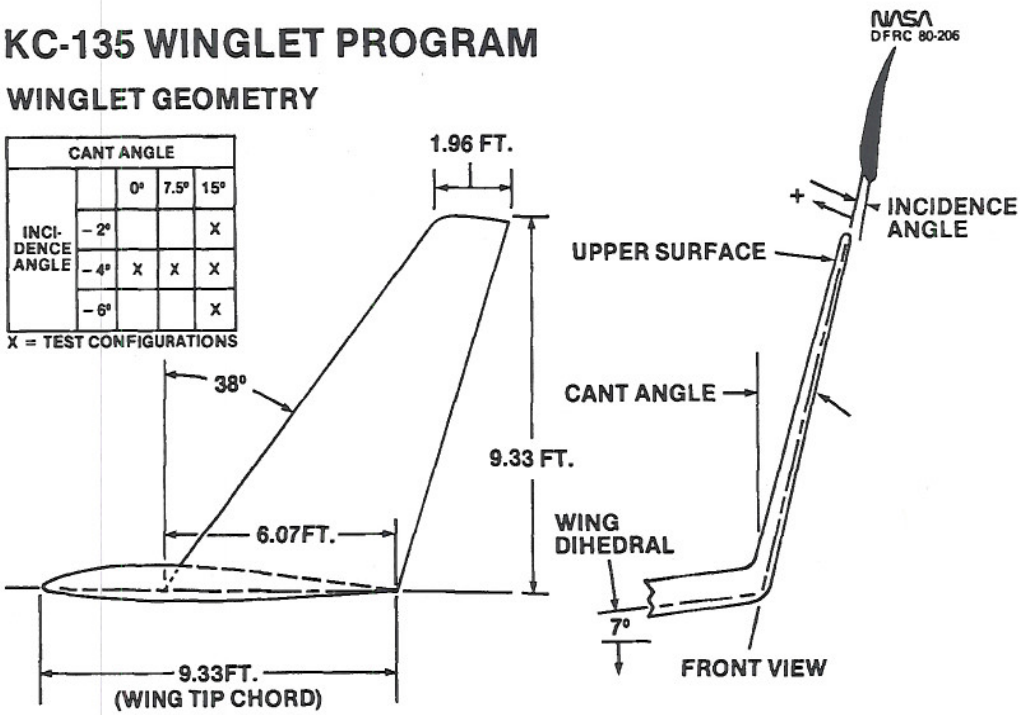


dedicated to expansion of the flight envelope, operational verification of the ground and airborne systems, and gaining operational experience of flying a high performance RPRV. Test data has been gathered at a maximum altitude of 40,000 feet and maximum Mach number of 0.93. Stability and control data has been taken at transonic

Mach numbers up to 0.90. In general, the flight test results are favorable with the exception of lower directional stability at low angles of attack and near zero sideslip angles. Flutter clearance flight results indicated a potential low damped canard oscillation at high transonic Mach numbers. This problem was resolved by reducing the free play of the canard flap. Intermittent data link losses were experienced in the initial flights which reduced the data acquisition time during the flights. Diversity combiner systems were incorporated in the ground and airborne data receiver systems that now provide a continuous data stream at all attitudes of the vehicle in flight. Other systems improvements have been incorporated as a result of the five flights to date. The joint NASA/USAF HiMAT program was formulated to promote and stimulate the application of new (high-risk) technology in a multidisciplinary manner so as to exploit the synergistic potential of new technology for the design of future fighter aircraft. Flight testing will be accomplished using RPRV test techniques with subscale vehicles to effect cost reductions over comparable manned vehicles. Flight test results hold the promise to provide data that are useful in upgrading analytic and ground test design methods and also determine the suitability of the subscale RPRV test technique for flight research. (Paul Loschke, ext. 754)

Transport Aircraft Systems Technology

Winglets Program. - Winglets are small, nearly vertical aerodynamic surfaces which are designed to be mounted at the tips of aircraft wings. They are found in nature



on all soaring birds that cant their tip feathers when they attempt to achieve high-lift flight.

Design optimization studies and wind-tunnel tests led by Dr. Whitcomb of the NASA Langley Research Center (LaRC) have shown that these extensions can produce significant increases in the lift-to-drag ratios on some of today's transport aircraft. The application of winglets to the USAF KC-135 tanker aircraft is predicted to increase its cruise lift-to-drag ratio by 8 percent. This increase would result in an average fuel savings of 60,000 gallons per airplane per year. If retrofitted to the KC-135 fleet, more than a billion dollars' worth of fuel could be saved over the next 20 years.

Therefore, the USAF and NASA have embarked on a joint program to obtain a full-scale evaluation of winglets on the KC-135 aircraft. The Boeing Company, under USAF contract, has constructed a set of flight-test winglets. NASA Dryden has instrumented a test airplane.

Fourteen test flights have been accomplished since the winglets were installed on the airplane. The flights have been flown with different cant and incidence angles on the winglets in order to provide data that would enable a tradeoff between aerodynamic performance gains and winglet-induced wing loads. To date, the results have confirmed that the winglets will yield a 7 percent decrease in the KC-135's total drag at

DRAG DECREASE RESULTING FROM WINGLETS ON THE KC-135. M = 0.78

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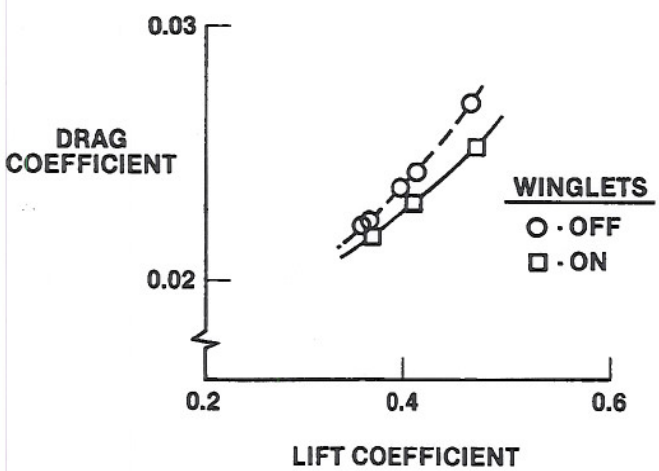

the cruise condition. This drag increment correlates well with the wind-tunnel predicted values. The flight-measured loads and stability and control characteristics also correlate well with the predicted values. The only unexpected flight result has been a flutter speed decrease when the winglets are in the 0° cant, and 4° incidence angle configuration. Since the decreased flutter speed only occurred

KC-135 WING AND WINGLET SPAN LOADS

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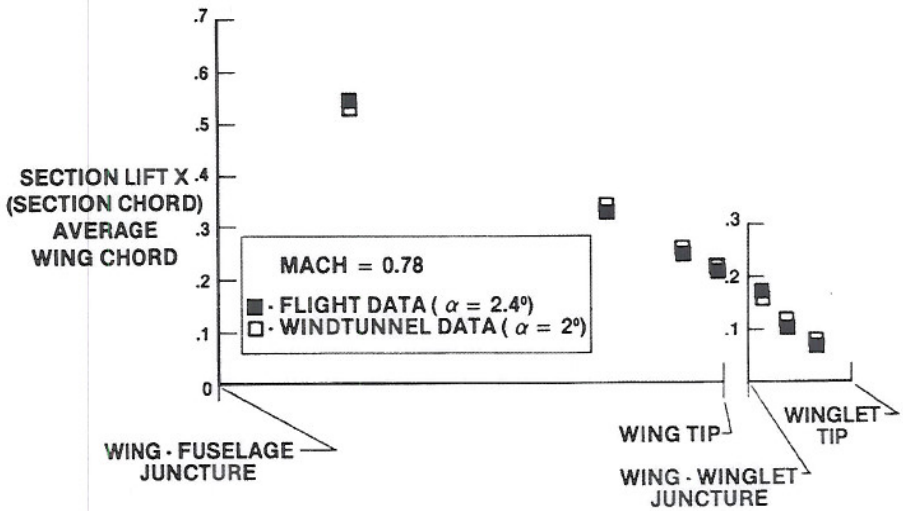


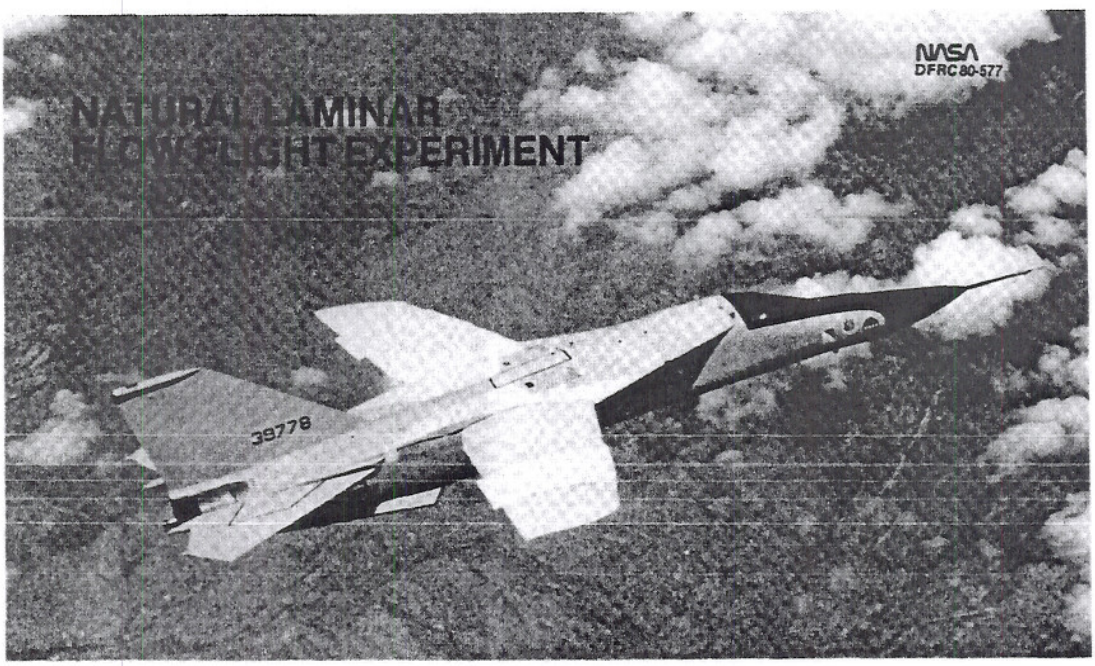
at the 0° cant and 4° incidence angle configuration and was not prevalent at the 15° cant and 4° incidence angle configuration, it does not detract from the promise of winglets. (Marvin R. Barber, ext. 275)

Natural Laminar Flow Experiment.- Significant improvements in the cruise efficiency of transport aircraft can be obtained if the flow over the wings is laminar. Active laminar flow control can prevent turbulent flow over most of the wing, but such systems add weight, cost, and complicate maintenance.

A possible alternative to active laminar flow control is natural laminar flow (NLF). Natural laminar flow does not involve complicated mechanisms or systems, but rather utilizes an airfoil shape which encourages laminar flow to extend farther over the airfoil shape than for conventional airfoils. The airfoil shape required is one which maintains a favorable pressure gradient over most of the chord. While the advantages of laminar flow for significantly improving aerodynamic efficiency are well known, the practical aspects of maintaining natural laminar flow have not been addressed at the higher Reynolds numbers and Mach numbers associated with commercial aircraft operations.

As part of the NASA aircraft energy efficiency program, a joint Dryden/Langley research effort has been initiated to investigate the feasibility of maintaining natural laminar flow on lifting surfaces. A supercritical airfoil section has been designed with favorable pressure gradients on both the upper and lower surfaces to determine the extent of natural laminar flow that can be obtained with promising consistency over both surfaces of this subsonic cruise airfoil. Wind tunnel tests in support of this experiment were conducted in the Langley Research Center 8-Foot Transonic Pressure Tunnel.

The outer wing panels of the F-111 TACT airplane were modified to incorporate the natural laminar flow airfoil, and instrumentation was installed to provide surface pressure data as well as for determining transition location and boundary layer characteristics.



The flight experiment encompassed a range of Mach numbers from 0.80 to 0.85 at altitudes of 25,000 feet and 30,000 feet, wing leading-edge sweep angles of 10° and 26°, and were conducted with and without transition fixed at several locations. Data analysis is underway, and the results are to be published in the near future. (Lawrence Montoya, ext. 534)

SPACE RESEARCH AND TECHNOLOGY BASE

Entry Fluid Physics Research and Technology

Flush Air Data System (FADS). - The shuttle entry air data system (SEADS), a joint Dryden/Langley research project, was originally developed at Langley to obtain reference air data during orbiter entry at Mach numbers above 2.0. The purpose of SEADS is to make pressure and temperature measurements that will permit the determination of vehicle free-stream conditions, angle of attack and sideslip, and other research air data parameters. Dryden has proposed to extend the application of SEADS for orbiter data below Mach 2 as well as for transonic aircraft in general. As a result, a series of subsonic wind tunnel tests and flight tests were conducted on a KC-135 airplane. The wind tunnel test results were reported in NASA TP-1642. The KC-135 flight data, reported at the 1980 Air Data Systems Conference at the USAF Academy, substantiated the subsonic wind tunnel data and indeed shows promise for subsonic/transonic aircraft application. Analyses of these data are continuing with transonic testing being planned using an F-14 airplane. (Terry Larson, ext. 435)

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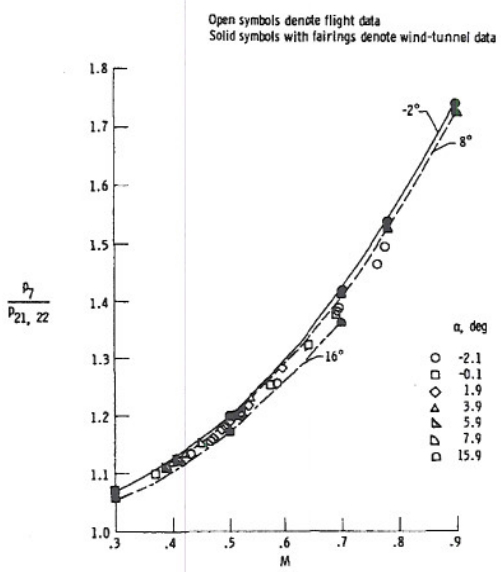
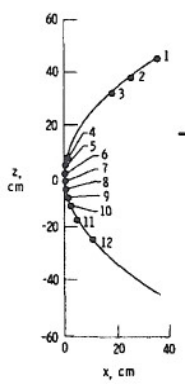
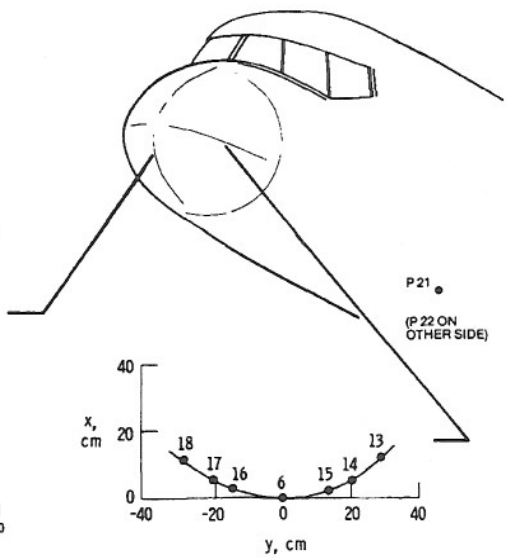
FLUSH AIR DATA SYSTEM (FADS)



DETERMINATION OF MACH NUMBER



VERTICAL PLANE ORIFICES



HORIZONTAL PLANE ORIFICES

Materials and Structures Research and Technology

René 41 Honeycomb Panel Tests. - A brazed René 41 honeycomb structural concept for integral LH_2 tankage has been developed under contract to Langley.

Two 12" X 72" panels were fabricated and are undergoing combined heating and loading cycling tests at DFRC. Two hundred of the 500 required boost and entry cycles have been successfully completed to date.

When qualified, this concept will contribute to a lower mass fraction for future space transportation vehicles. (Leslie Gong, ext. 767)

OEX - Structural Temperature Program. - Thermal stress predictions play an important part in the design of space transportation vehicles. Experience gained in the YF-12 loads research program and the orbiter development indicate that a weak link in these predictions involves the detailed definition of structural temperature distributions. An orbiter flight experiment (OEX) has been proposed and approved to develop and install infrared scanning devices in the orbiter wing which will provide detailed structural temperature definition for comparison with predictions from new analysis computer programs such as SPAR. (Roger Fields, ext. 748)

OFFICE OF SPACE SCIENCE

Remote Piloting Procedures. - As part of Dryden's continuing development of expertise in teleoperator control of aircraft, special video systems for remotely piloted vehicles (RPRV's) have been studied. A stereo TV system was briefly evaluated but was not shown to be advantageous. A variable acuity wide angle projection system has been constructed to take advantage of the motion cues provided by a peripheral visual field. When research in operator techniques and workload effects of this wide-angle system is completed, the system will be available for operational use on any RPV. (Terrence Rezek, ext. 606)

OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

Aerodynamics of Ground Vehicles. - One-twenty-fifth scale wind-tunnel tests have been conducted on models of advanced derivative tractor-trailer configurations. The annual fuel savings projected for the U.S. fleet of cab-over-engine tractor trailer trucks when employing various degrees of aerodynamic refinement range from 4.2 million kiloliters (26.3 million barrels) to 8.3 million kiloliters (52.3 million barrels). Over-the-highway fuel consumption tests with full-scale tractor-trailers provided correction factors which were used in the analysis of the model data.

The foregoing projected fuel savings amount to from 17 percent to 34 percent of the imported diesel fuel refined for highway use.

Follow-on model testing has been completed on two additional truck configurations which have been tested at full scale at Dryden. This will permit the over-the-highway fuel consumption results for these configurations to be adjusted for average national wind effects so that fuel saving projections analogous to the foregoing may be made for two additional configurations. (Edwin Saltzman, ext. 378)

OFFICE OF SPACE TRANSPORTATION SYSTEMS

Orbiter Landing Investigation. - The orbiter landing investigation reported in the Dryden FY 78 and FY 79 annual reports has been continued in FY 80. The latest efforts consisted of stress tests of several pilot-induced oscillation (PIO) suppressors using the Calspan Total In-flight Simulator (TIFS) airplane and the new Ames Vertical Motion Simulation (VMS) facility.

The TIFS tests consisted of a 2 week 16 flight program in October 1979 in which over 150 approaches were made by seven test pilots - including 11 by the STS-1 Commander.

It was determined that the originally recommended PIO suppressor was not acceptable because it caused excessive loss of control authority. Two modified filters were demonstrated that minimized control loss but provided significant protection against a PIO. One of these configurations (D-3) was selected as modification to STS-1 flight control system (FCS).

A follow-on program was run in the new Ames VMS facility in the spring of 1980 to obtain additional confidence in the STS-1 control system and to explore several candidate modifications for improved controllability. In excess of 1000 landings were simulated using 12 pilots including 218 landings by the prime and back-up STS-1 crew members.

The results verified that the landing control system with the D-3 suppressor was adequate for initial flights but latent PIO tendencies were still evidenced. A modified FCS with the addition of normal acceleration feedback improved flight path control and significantly reduced touchdown sink speed as compared to the current STS-1 configuration. It was recommended that Rockwell determine the feasibility of implementing the improved FCS for early operational flights. (Joseph Weil, ext. 638)

STS Development Engineering Support. - The space shuttle program manager has requested Dryden, because of its broad experience with reentry and unconventional aircraft, to assist the shuttle program in various areas of the flight test development program.

The key evaluation tool being used for this program is a six degree-of-freedom simulation of the orbiter's aerodynamics, flight control and guidance systems, and the environment. Dryden's effort will consist of an independent analysis and evaluation of the handling qualities/flight control system adequacy, parameter identification techniques and application, and aero-thermal elastic loads of the orbiter from entry through landing. Major effort expended on this task in FY 80 was in designing, programming, and validating the entry simulation initial studies and concentrating on the STS-1 flight profile. (Richard Day, ext. 638)

Space Shuttle Orbital Flight Test. - During FY 1980, Dryden continued to perform maintenance and checkout flights on the Boeing 747 shuttle carrier aircraft. Modifications to the mate-demate device were completed in preparation for the post-flight processing of the space shuttle Columbia. The microwave scanning beam landing system (MSBLS) was installed on Rogers Dry Lake Runway 23 for the orbiter landings, and MSBLS checkout began. The installation of systems in the orbiter

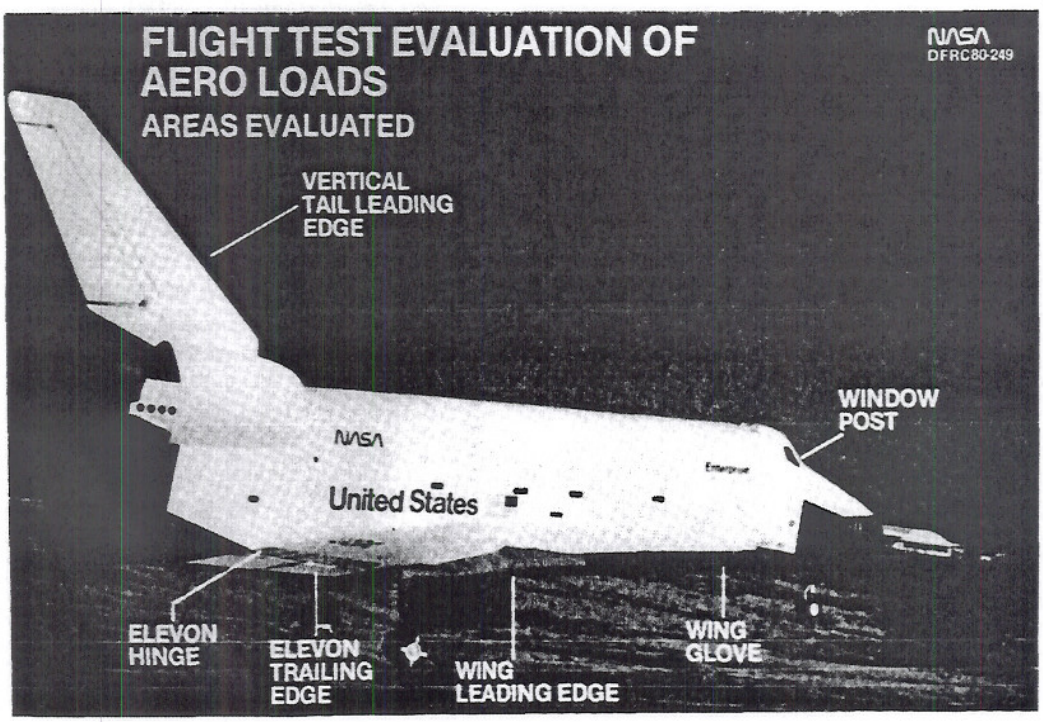
hangar for post-flight processing also began. A major portion of the orbiter ground support equipment was received and checked out. (Denis Bessette, ext. 544)

NASA Structures Team. - NASA Headquarters asked JSC to form a team of structural engineers from the various NASA Centers to make an independent assessment of the predicted stresses and deflections for the orbiter tiles and airframe.

The group was assembled on site at Rockwell International/Downey and addressed itself to the disciplinary areas of tile stress analysis, tile loads, airframe buckling, and thermal stresses. Investigations involved review of contractor analytical methods and models, prediction/test comparisons, and independent analyses. These activities resulted in discovery of problem areas and recommendations for corrective action which were presented to NASA and Rockwell management at monthly reviews.

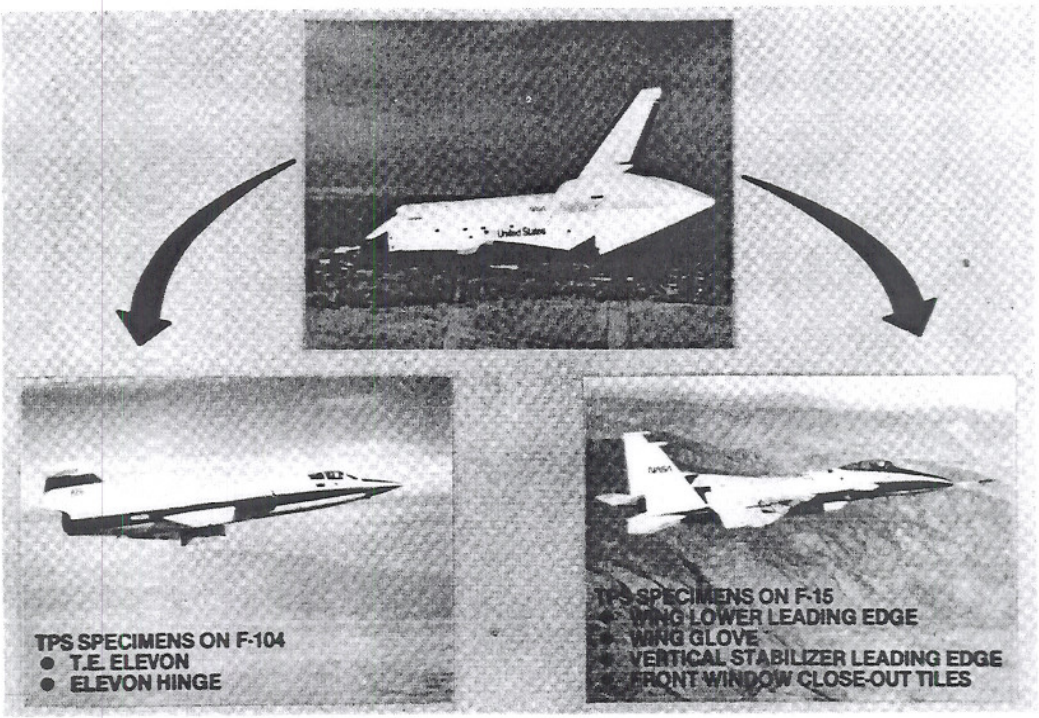
Dryden's participation consisted of on-site reviews of contractor data and independent thermal stress analysis and in-house independent surface heating and heat transfer analyses. This in-house effort is continuing. (Alan Carter, ext. 453)

Shuttle Thermal Protection System Airloads Flight Test Program. - Flight tests to determine the effects of airloads on the space shuttle orbiter thermal protection system (TPS) are being conducted at the NASA Dryden Flight Research Center. Several areas of the TPS on the orbiter have been identified for flight test evaluation.



For each area, test specimens are constructed to simulate the full-scale vehicle outer mold lines and geometric shape. Production TPS tiles and gap fillers are used and installed in accordance with the production specifications currently employed to install the same elements on the OV-102 orbiter vehicle.

The test specimens are then mounted on F-15 and F-104 research aircraft in an attempt to simulate the local flow conditions existing on the orbiter. These aircraft were

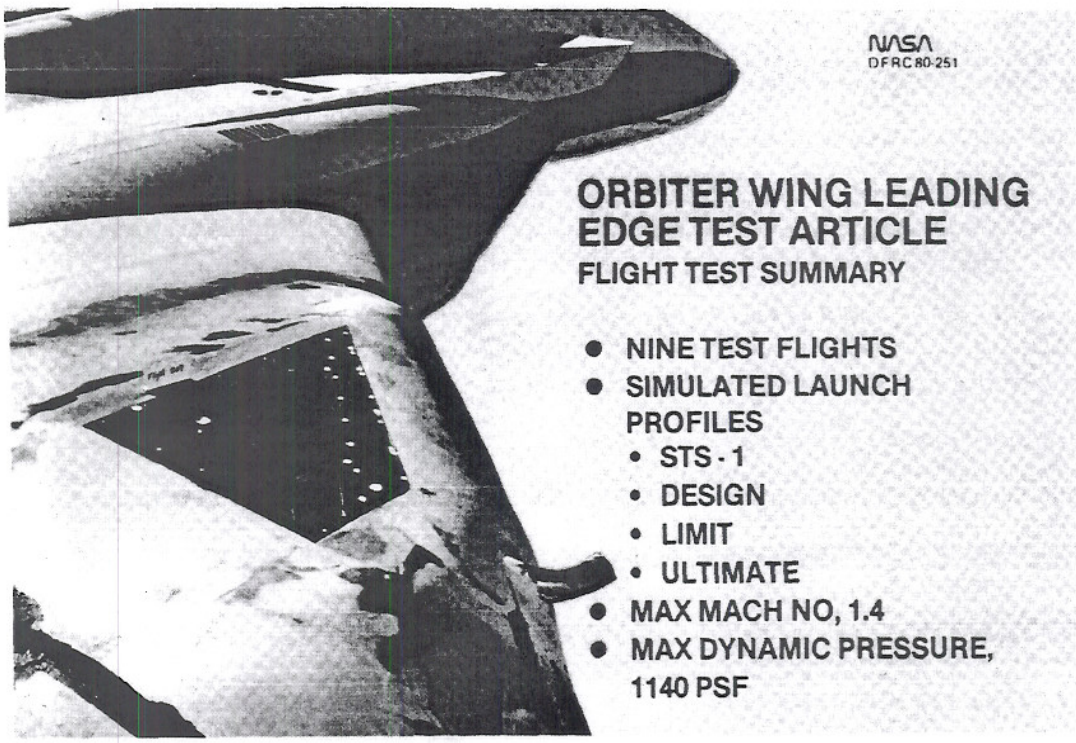


selected because of their ability to achieve the high speed and high dynamic pressures required to simulate the shuttle launch environment.

In attaching the test specimen to the aircraft, each specimen is configured to the outer mold line curvature of the orbiter, with fiber glass fairings or ramps used to blend the article to the surrounding aircraft surface. Pressure instrumentation installed on each test article is used to measure local flow on the aircraft and to verify that the pressure distribution on each test specimen approximates the pressure distribution expected on the orbiter in the region under study.

Nine test flights have been performed on the test article attached to the upper leading edge of the right hand wing surface of the F-15 aircraft. These tests simulated shuttle launch profiles for different missions. The article was tested to a maximum Mach number of 1.4 and a maximum dynamic pressure of 1140 psf. Tile rotation was found to occur under nominal airloads, causing gap widening and gap filler extrusion into the airstream. The resulting redesign of the tile attachment plate and gap filler assemblies has alleviated these problems, and successful retesting has verified satisfactory performance.

Flight testing of other TPS articles is expected to continue through December 1980. (Calvin Jarvis, ext. 237)



Low Gravity Flights. - Dryden Flight Research Center has initiated low gravity flights in response to a Marshall Space Flight Center request. The trajectories are between 40 and 60 seconds in length. They provide approximately 30 seconds where the maximum acceleration is 0.03g in any axis. The trajectories are flown in a TF-104G.

To date, experiments have been carried in an aft electronic bay of the F-104. The experiment consists of photographing a solution which crystallizes under low g conditions. Future experiments will probably be similar observations of convective currents, nucleation, and crystallization under low g.

These trajectories provide reasonably low g environments for intermediate time intervals at minimum cost. The service is viewed as open ended; it is provided on a demand basis when investigations at other Centers or agencies require it and aircraft availability permits it. (Victor Horton, ext. 201)

OFFICE OF SPACE TRACKING AND DATA SYSTEMS

NASA Aeronautical Test Range. - The NASA aeronautical test range (ATR) has made significant strides in preparation for the flight test requirements of the late 1980's and the 1990's. As described below, all three of the major systems areas (communications systems, ground telemetry systems, and space positioning systems) in the ATR are being upgraded.

Communications systems: The range communications system (RACOMM) is continuing to expand its sphere of coverage and capability. All modifications for the tilt rotor research aircraft are in place and operating. Final modifications for the shuttle will

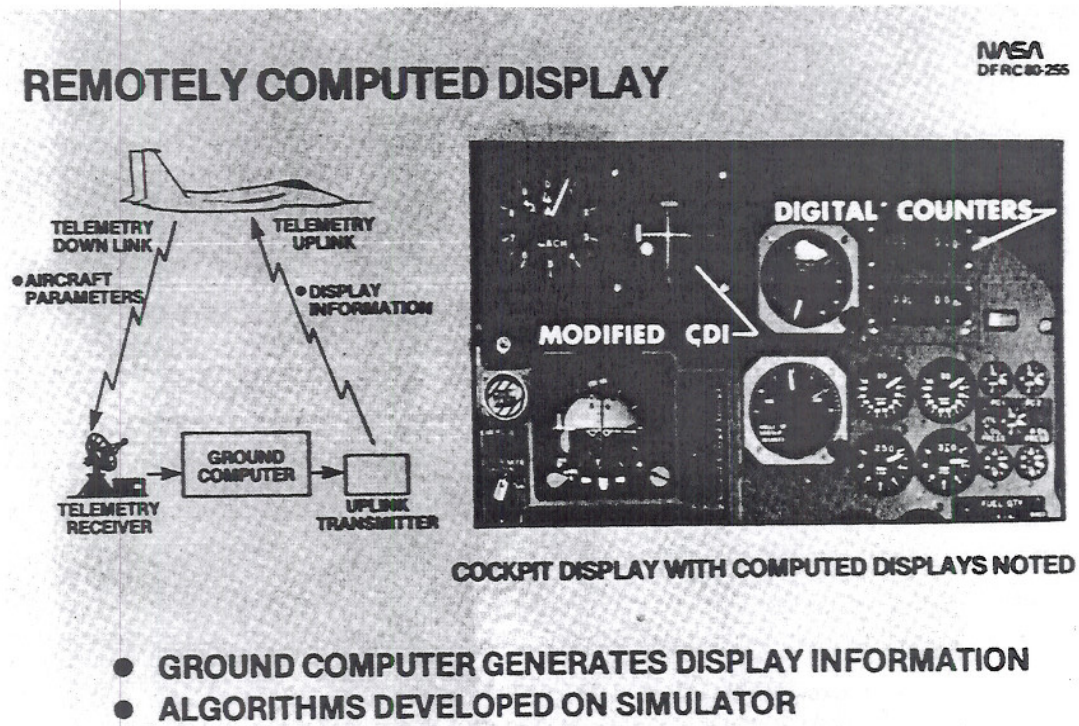
be complete by the end of the calendar year. In the video system arena, new optics have been purchased for the long range optics system and the bore sight on the triplex telemetry antenna. These installations will also be complete by the end of 1980.

Ground telemetry systems: Integration of two SEL 32/55 computers in the telemetry acquisition system (TAS) will be complete by the end of 1980. This integration will result in a four stream capability for the TAS. The purchase of two SEL 32/77's has been completed for the telemetry processing system (TPS). The delivery of TPS number 1 occurred in October of 1980, and TPS number 2 is scheduled for July of 1981. These two new real time processors will more than double the throughput rate of the ATR systems. Prototype work has begun for the eventual implementation of intelligent consoles in the mission control centers (MCC's). Software configurable, color CRT displays are already operational. The modal/spectral analysis facility (SAF) more than doubled its output capability as a result of TRRA requirements. In addition, a 12 channel GenRad spectral analysis system has been added to support the upcoming turboprop program.

Space positioning systems: Procurement has been initiated for a new target acquisition and data collection (TACDAC) system and should be operational by the second quarter of FY 83. A future direction study is being initiated to enable the ATR to be ready for the space positioning options and requirements of the future. Major software activities to support a dual MCC concept will be completed by the end of 1980.

These represent but the highlights of the activities in the ATR. Other activities that span system boundaries such as graphics and video networking are also in the planning phase. The focus of these activities is seen in the Dryden mission control centers. The Blue Room pictured below reached operational status in early CY 80. It presently supports all aeronautics test missions at DFRC. Its companion room, the Gold Room, will be operational by the end of CY 1980 to support shuttle missions terminating at the Edwards complex.

The mission control center is a focal point during research missions. A highly skilled team of engineers and technicians works together in the MCC to monitor, control and interpret flight research results. One of the tools that has proven the value of an integrated approach is that of remotely computed displays (RCD). Concepts, algorithms, and hardware are developed on ground-based simulators. These are then implemented on both the vehicle and ground-based real time computers as depicted below. Given the complexity of test point conditions and the piloting task to



get to these test points, the RCD approach has greatly increased the productivity of a mission and allowed for better information for decision making in the real-time environment. (Jack Kleinkopf, ext. 706 and Archie Moore, ext. 482)

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FY 1980

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5. Swaroop, Ram; Brownlow, James D.; and Winter, William R.: Extreme Mean and its Applications. NASA TM-81346.

6. Sefic, Walter J.: Friction Characteristics of Steel Skids Equipped with Skegs on a Lakebed Surface. NASA TM-81347.

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16. Larson, Terry J.; Flechner, Stuart G.; and Siemers, Paul M. III: Wind Tunnel Investigation of an All Flush Orifice Air Data System for a Large Subsonic Aircraft. NASA TP-1642.

17. Ko, William L.: Comparison of Structural Behavior of Superplastically Formed/ Diffusion-Bonded Sandwich Structures and Honeycomb Core Sandwich Structures. NASA TM-81348.

18. Gilyard, Glenn B.; and Burken, John J.: Development and Flight Test Results of an Autothrottle Control System at Mach 3 Cruise. NASA TP-1621.

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R & T FLIGHT ACTIVITIES SUMMARY

PROGRAM	AIRCRAFT	FLIGHTS
10° Cone	F-15 #287	13
Digital Fly-by-Wire	F-8 #802	17
Winglets	KC-135 #129	23
Natural Laminar Flow	F-111 #778	17
Aileron Rudder Interconnect (ARI)	F-14 #991	41
JetStar Turboprop	C-140 #814	5
HiMAT (Captive and drop flights)	HiMAT #870	7
Skew Wing Program (Oblique Wing)	AD-1 #805	18
F-111 Flutter Program	F-111 #778	2
Flush Air Data Systems (FADS)	KC-135 #930	2
Gossamer Albatross	Albatross #2	17
HUD Calspan	T-33 #120	9
Zero "G"	F-104 #825	8
Wake Vortex Upset Alleviation	B-747 #RA001	10
	L1011	4
	T-37 #807	10
	PA-30 #808	5
DAST		
Captive and drop flights	Firebee	4
TV Landings	F-104 #824	4
B-52 Research Support	B-52 #008	12
Shuttle Program		
F-15 Tile Test	F-15 #281	22
F-104 Tile Test	F-104 #826	26
MSBLS	C-140 #814	7
Total In-Flight Simulator (TIFS)	C-131 #793	16
TOTAL		299

NOTE: Accomplishment of these R & T flight activities also requires many supporting flights each year with these and other Center aircraft.